

52. IWK

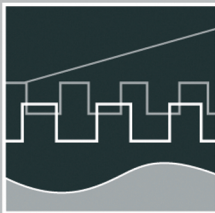
Internationales Wissenschaftliches Kolloquium
International Scientific Colloquium



PROCEEDINGS

| 10 - 13 September 2007

FACULTY OF COMPUTER SCIENCE AND AUTOMATION



COMPUTER SCIENCE MEETS AUTOMATION

VOLUME I

Session 1 - Systems Engineering and Intelligent Systems

Session 2 - Advances in Control Theory and Control Engineering

**Session 3 - Optimisation and Management of Complex
Systems and Networked Systems**

Session 4 - Intelligent Vehicles and Mobile Systems

Session 5 - Robotics and Motion Systems



Bibliografische Information der Deutschen Bibliothek

Die Deutsche Bibliothek verzeichnet diese Publikation in der deutschen Nationalbibliografie; detaillierte bibliografische Daten sind im Internet über <http://dnb.ddb.de> abrufbar.

ISBN 978-3-939473-17-6

Impressum

- Herausgeber: Der Rektor der Technischen Universität Ilmenau
Univ.-Prof. Dr. rer. nat. habil. Peter Scharff
- Redaktion: Referat Marketing und Studentische Angelegenheiten
Kongressorganisation
Andrea Schneider
Tel.: +49 3677 69-2520
Fax: +49 3677 69-1743
e-mail: kongressorganisation@tu-ilmenau.de
- Redaktionsschluss: Juli 2007
- Verlag: 
Technische Universität Ilmenau/Universitätsbibliothek
Universitätsverlag Ilmenau
Postfach 10 05 65
98684 Ilmenau
www.tu-ilmenau.de/universitaetsverlag
- Herstellung und Auslieferung: Verlagshaus Monsenstein und Vannerdat OHG
Am Hawerkamp 31
48155 Münster
www.mv-verlag.de
- Layout Cover: www.cey-x.de
- Bezugsmöglichkeiten: Universitätsbibliothek der TU Ilmenau
Tel.: +49 3677 69-4615
Fax: +49 3677 69-4602

© Technische Universität Ilmenau (Thür.) 2007

Diese Publikationen und alle in ihr enthaltenen Beiträge und Abbildungen sind urheberrechtlich geschützt. Mit Ausnahme der gesetzlich zugelassenen Fälle ist eine Verwertung ohne Einwilligung der Redaktion strafbar.

Preface

Dear Participants,

Confronted with the ever-increasing complexity of technical processes and the growing demands on their efficiency, security and flexibility, the scientific world needs to establish new methods of engineering design and new methods of systems operation. The factors likely to affect the design of the smart systems of the future will doubtless include the following:

- As computational costs decrease, it will be possible to apply more complex algorithms, even in real time. These algorithms will take into account system nonlinearities or provide online optimisation of the system's performance.
- New fields of application will be addressed. Interest is now being expressed, beyond that in "classical" technical systems and processes, in environmental systems or medical and bioengineering applications.
- The boundaries between software and hardware design are being eroded. New design methods will include co-design of software and hardware and even of sensor and actuator components.
- Automation will not only replace human operators but will assist, support and supervise humans so that their work is safe and even more effective.
- Networked systems or swarms will be crucial, requiring improvement of the communication within them and study of how their behaviour can be made globally consistent.
- The issues of security and safety, not only during the operation of systems but also in the course of their design, will continue to increase in importance.

The title "Computer Science meets Automation", borne by the 52nd International Scientific Colloquium (IWK) at the Technische Universität Ilmenau, Germany, expresses the desire of scientists and engineers to rise to these challenges, cooperating closely on innovative methods in the two disciplines of computer science and automation.

The IWK has a long tradition going back as far as 1953. In the years before 1989, a major function of the colloquium was to bring together scientists from both sides of the Iron Curtain. Naturally, bonds were also deepened between the countries from the East. Today, the objective of the colloquium is still to bring researchers together. They come from the eastern and western member states of the European Union, and, indeed, from all over the world. All who wish to share their ideas on the points where "Computer Science meets Automation" are addressed by this colloquium at the Technische Universität Ilmenau.


All the University's Faculties have joined forces to ensure that nothing is left out. Control engineering, information science, cybernetics, communication technology and systems engineering – for all of these and their applications (ranging from biological systems to heavy engineering), the issues are being covered.

Together with all the organizers I should like to thank you for your contributions to the conference, ensuring, as they do, a most interesting colloquium programme of an interdisciplinary nature.

I am looking forward to an inspiring colloquium. It promises to be a fine platform for you to present your research, to address new concepts and to meet colleagues in Ilmenau.



Professor Peter Scharff
Rector, TU Ilmenau



Professor Christoph Ament
Head of Organisation

CONTENTS

	Page
1 Systems Engineering and Intelligent Systems	
A. Yu. Nedelina, W. Fengler DIPLAN: Distributed Planner for Decision Support Systems	3
O. Sokolov, M. Wagenknecht, U. Gocht Multiagent Intelligent Diagnostics of Arising Faults	9
V. Nissen Management Applications of Fuzzy Control	15
O. G. Rudenko, A. A. Bessonov, P. Otto A Method for Information Coding in CMAC Networks	21
Ye. Bodyanskiy, P. Otto, I. Pliss, N. Teslenko Nonlinear process identification and modeling using general regression neuro-fuzzy network	27
Ye. Bodyanskiy, Ye. Gorshkov, V. Kolodyazhniy, P. Otto Evolving Network Based on Double Neo-Fuzzy Neurons	35
Ch. Wachten, Ch. Ament, C. Müller, H. Reinecke Modeling of a Laser Tracker System with Galvanometer Scanner	41
K. Lüttkopf, M. Abel, B. Eylert Statistics of the truck activity on German Motorways	47
K. Meissner, H. Hensel A 3D process information display to visualize complex process conditions in the process industry	53
F.-F. Steege, C. Martin, H.-M. Groß Recent Advances in the Estimation of Pointing Poses on Monocular Images for Human-Robot Interaction	59
A. González, H. Fernlund, J. Ekblad After Action Review by Comparison – an Approach to Automatically Evaluating Trainee Performance in Training Exercise	65
R. Suzuki, N. Fujiki, Y. Taru, N. Kobayashi, E. P. Hofer Internal Model Control for Assistive Devices in Rehabilitation Technology	71
D. Sommer, M. Golz Feature Reduction for Microsleep Detection	77

F. Müller, A. Wenzel, J. Wernstedt A new strategy for on-line Monitoring and Competence Assignment to Driver and Vehicle	83
V. Borikov Linear Parameter-Oriented Model of Microplasma Process in Electrolyte Solutions	89
A. Avshalumov, G. Filaretov Detection and Analysis of Impulse Point Sequences on Correlated Disturbance Phone	95
H. Salzwedel Complex Systems Design Automation in the Presence of Bounded and Statistical Uncertainties	101
G. J. Nalepa, I. Wojnicki Filling the Semantic Gaps in Systems Engineering	107
R. Knauf Compiling Experience into Knowledge	113
R. Knauf, S. Tsuruta, Y. Sakurai Toward Knowledge Engineering with Didactic Knowledge	119
 2 Advances in Control Theory and Control Engineering	
U. Konigorski, A. López Output Coupling by Dynamic Output Feedback	129
H. Toossian Shandiz, A. Hajipoor Chaos in the Fractional Order Chua System and its Control	135
O. Katernoga, V. Popov, A. Potapovich, G. Davydau Methods for Stability Analysis of Nonlinear Control Systems with Time Delay for Application in Automatic Devices	141
J. Zimmermann, O. Sawodny Modelling and Control of a X-Y-Fine-Positioning Table	145
A. Winkler, J. Suchý Position Based Force Control of an Industrial Manipulator	151
E. Arnold, J. Neupert, O. Sawodny, K. Schneider Trajectory Tracking for Boom Cranes Based on Nonlinear Control and Optimal Trajectory Generation	157

K. Shaposhnikov, V. Astakhov The method of ortogonal projections in problems of the stationary magnetic field computation	165
J. Naumenko The computing of sinusoidal magnetic fields in presence of the surface with bounded conductivity	167
K. Bayramkulov, V. Astakhov The method of the boundary equations in problems of computing static and stationary fields on the topological graph	169
T. Kochubey, V. Astakhov The computation of magnetic field in the presence of ideal conductors using the Integral-differential equation of the first kind	171
M. Schneider, U. Lehmann, J. Krone, P. Langbein, Ch. Ament, P. Otto, U. Stark, J. Schrickel Artificial neural network for product-accompanied analysis and control	173
I. Jawish The Improvement of Traveling Responses of a Subway Train using Fuzzy Logic Techniques	179
Y. Gu, H. Su, J. Chu An Approach for Transforming Nonlinear System Modeled by the Feedforward Neural Networks to Discrete Uncertain Linear System	185
3 Optimisation and Management of Complex Systems and Networked Systems	
R. Franke, J. Doppelhammer Advanced model based control in the Industrial IT System 800xA	193
H. Gerbracht, P. Li, W. Hong An efficient optimization approach to optimal control of large-scale processes	199
T. N. Pham, B. Wutke Modifying the Bellman's dynamic programming to the solution of the discrete multi-criteria optimization problem under fuzziness in long-term planning	205
S. Ritter, P. Bretschneider Optimale Planung und Betriebsführung der Energieversorgung im liberalisierten Energiemarkt	211
P. Bretschneider, D. Westermann Intelligente Energiesysteme: Chancen und Potentiale von IuK-Technologien	217

Z. Lu, Y. Zhong, Yu. Wu, J. Wu WSReMS: A Novel WSDM-based System Resource Management Scheme	223
M. Heit, E. Jennenchen, V. Kruglyak, D. Westermann Simulation des Strommarktes unter Verwendung von Petrinetzen	229
O. Sauer, M. Ebel Engineering of production monitoring & control systems	237
C. Behn, K. Zimmermann Biologically inspired Locomotion Systems and Adaptive Control	245
J. W. Vervoorst, T. Kopfstedt Mission Planning for UAV Swarms	251
M. Kaufmann, G. Bretthauer Development and composition of control logic networks for distributed mechatronic systems in a heterogeneous architecture	257
T. Kopfstedt, J. W. Vervoorst Formation Control for Groups of Mobile Robots Using a Hierarchical Controller Structure	263
M. Abel, Th. Lohfelder Simulation of the Communication Behaviour of the German Toll System	269
P. Hilgers, Ch. Ament Control in Digital Sensor-Actuator-Networks	275
C. Saul, A. Mitschele-Thiel, A. Diab, M. Abd rabou Kalil A Survey of MAC Protocols in Wireless Sensor Networks	281
T. Rossbach, M. Götze, A. Schreiber, M. Eifart, W. Kattanek Wireless Sensor Networks at their Limits – Design Considerations and Prototype Experiments	287
Y. Zhong, J. Ma Ring Domain-Based Key Management in Wireless Sensor Network	293
V. Nissen Automatic Forecast Model Selection in SAP Business Information Warehouse under Noise Conditions	299
M. Kühn, F. Richter, H. Salzwedel Process simulation for significant efficiency gains in clinical departments – practical example of a cancer clinic	305

D. Westermann, M. Kratz, St. Kümmerling, P. Meyer Architektur eines Simulators für Energie-, Informations- und Kommunikations- technologien	311
P. Moreno, D. Westermann, P. Müller, F. Büchner Einsatzoptimierung von dezentralen netzgekoppelten Stromerzeugungs- anlagen (DEA) in Verteilnetzen durch Erhöhung des Automatisierungsgrades	317
M. Heit, S. Rozhenko, M. Kryvenka, D. Westermann Mathematische Bewertung von Engpass-Situationen in Transportnetzen elektrischer Energie mittels lastflussbasierter Auktion	331
M. Lemmel, M. Schnatmeyer RFID-Technology in Warehouse Logistics	339
V. Krugljak, M. Heit, D. Westermann Approaches for modelling power market: A Comparison.	345
St. Kümmerling, N. Döring, A. Friedemann, M. Kratz, D. Westermann Demand-Side-Management in Privathaushalten – Der eBox-Ansatz	351
4 Intelligent Vehicles and Mobile Systems	
A. P. Aguiar, R. Ghabchelloo, A. Pascoal, C. Silvestre , F. Vanni Coordinated Path following of Multiple Marine Vehicles: Theoretical Issues and Practical Constraints	359
R. Engel, J. Kalwa Robust Relative Positioning of Multiple Underwater Vehicles	365
M. Jacobi, T. Pfützenreuter, T. Glotzbach, M. Schneider A 3D Simulation and Visualisation Environment for Unmanned Vehicles in Underwater Scenarios	371
M. Schneider, M. Eichhorn, T. Glotzbach, P. Otto A High-Level Simulator for heterogeneous marine vehicle teams under real constraints	377
A. Zangrilli, A. Picini Unmanned Marine Vehicles working in cooperation: market trends and technological requirements	383
T. Glotzbach, P. Otto, M. Schneider, M. Marinov A Concept for Team-Orientated Mission Planning and Formal Language Verification for Heterogeneous Unmanned Vehicles	389

M. A. Arredondo, A. Cormack SeeTrack: Situation Awareness Tool for Heterogeneous Vehicles	395
J. C. Ferreira, P. B. Maia, A. Lucia, A. I. Zapaniotis Virtual Prototyping of an Innovative Urban Vehicle	401
A. Wenzel, A. Gehr, T. Glotzbach, F. Müller Superfour-in: An all-terrain wheelchair with monitoring possibilities to enhance the life quality of people with walking disability	407
Th. Krause, P. Protzel Verteiltes, dynamisches Antriebssystem zur Steuerung eines Luftschiffes	413
T. Behrmann, M. Lemmel Vehicle with pure electric hybrid energy storage system	419
Ch. Schröter, M. Höchemer, H.-M. Groß A Particle Filter for the Dynamic Window Approach to Mobile Robot Control	425
M. Schenderlein, K. Debes, A. Koenig, H.-M. Groß Appearance-based Visual Localisation in Outdoor Environments with an Omnidirectional Camera	431
G. Al Zeer, A. Nabout, B. Tibken Hindernisvermeidung für Mobile Roboter mittels Ausweichecken	437
 5 Robotics and Motion Systems	
Ch. Schröter, H.-M. Groß Efficient Gridmaps for SLAM with Rao-Blackwellized Particle Filters	445
St. Müller, A. Scheidig, A. Ober, H.-M. Groß Making Mobile Robots Smarter by Probabilistic User Modeling and Tracking	451
A. Swerdlow, T. Machmer, K. Kroschel, A. Laubenheimer, S. Richter Opto-acoustical Scene Analysis for a Humanoid Robot	457
A. Ahranovich, S. Karpovich, K. Zimmermann Multicoordinate Positioning System Design and Simulation	463
A. Balkovoy, V. Cacenkin, G. Slivinskaia Statical and dynamical accuracy of direct drive servo systems	469
Y. Litvinov, S. Karpovich, A. Ahranovich The 6-DOF Spatial Parallel Mechanism Control System Computer Simulation	477

V. Lysenko, W. Mintchenya, K. Zimmermann 483
Minimization of the number of actuators in legged robots using
biological objects

J. Kroneis, T. Gastauer, S. Liu, B. Sauer 489
Flexible modeling and vibration analysis of a parallel robot with
numerical and analytical methods for the purpose of active vibration damping

A. Amthor, T. Hausotte, G. Jäger, P. Li 495
Friction Modeling on Nanometerscale and Experimental Verification

Paper submitted after copy deadline

2 Advances in Control Theory and Control Engineering

V. Piwek, B. Kuhfuss, S. Allers
Feed drivers – Synchronized Motion is leading to a process optimization 503

V. Lysenko, W. Mintchenya, K. Zimmermann 483
Minimization of the number of actuators in legged robots using
biological objects

J. Kroneis, T. Gastauer, S. Liu, B. Sauer 489
Flexible modeling and vibration analysis of a parallel robot with
numerical and analytical methods for the purpose of active vibration damping

A. Amthor, T. Hausotte, G. Jäger, P. Li 495
Friction Modeling on Nanometerscale and Experimental Verification

Paper submitted after copy deadline

2 Advances in Control Theory and Control Engineering

V. Piwek, B. Kuhfuss, S. Allers
Feed drivers – Synchronized Motion is leading to a process optimization 503

A. Ahranovich / S. Karpovich / K. Zimmermann

Multicoordinate Positioning System Design and Simulation

ABSTRACT

The approach of multicoordinate positioning control system with parallel kinematics level division is described in the paper. By such system hierarchy definition, the information integrity is achieved. One of the most effective motion program building approaches is based on holonomic automatic systems, whereas this approach presupposes some definite structure of differential analyzer working-out. This structure enables motion program building in a uniform and transparent form enabling affix dynamics control.

TRIPLANAR CONTROL SYSTEM HIERARCHY

Triplanar [1] is a multicoordinate complex positioning system with 6 degrees of freedom. Like any other complex equipment's control system, Triplanar's one is divided into several levels aiming to represent the information and functional integrity of each of them. Each control level is based on the lower one, so by such means the information integrity is achieved. Fig. 1 represents the block-diagram of Triplanar control system.

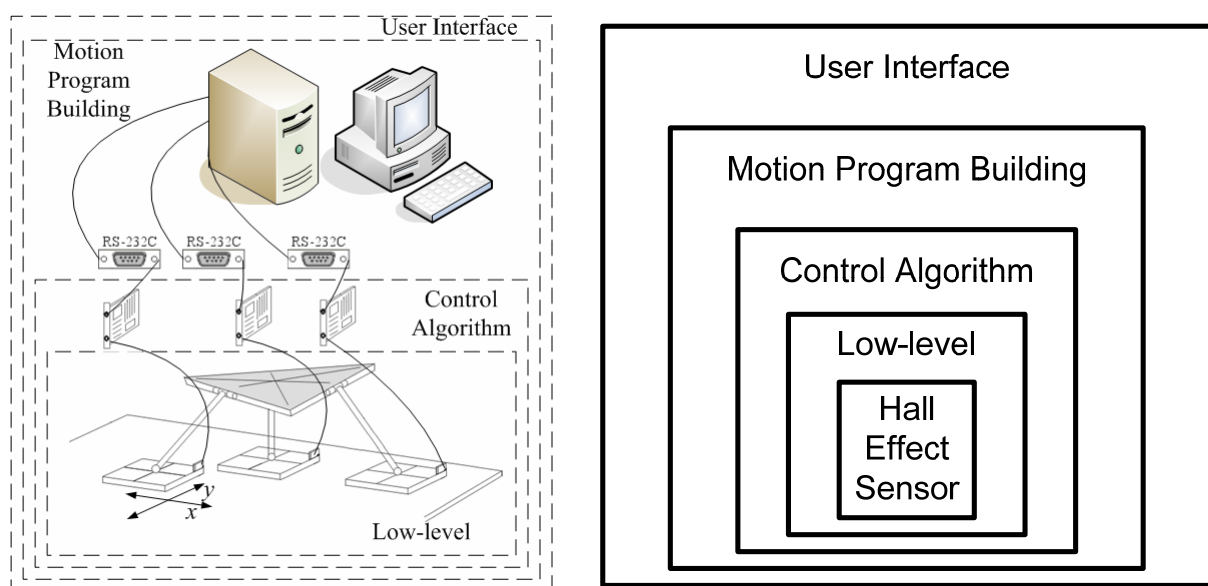


Fig. 1 Triplanar Control Levels

The general upper level software aims to bring user commands to the lower level. The input interface of the general software is user interface. The Motion Program Building level is supposed to build motion program basing on user input data and pass control signals to the lower system. While plenty of motion program building algorithms exist, the current work discusses one which is based on holonomic automatic systems.

MOTION PROGRAM BUILDING

The motion program building is based on differential analyzers synthesis. This approach enables easy parameterization of initial equations connecting system variables and therefore, it enables position demands generation on any topological manifold which is described with the help of equation:

$$F_j(t, x_1, x_2, \dots, x_n) = 0; \quad j = 1, 2, \dots, m \quad (1)$$

The first-order system of differential equations:

$$\frac{dx_i}{d\varphi} = f_i, i = 1, 2, \dots, n, \quad (2)$$

the solution of which satisfies the equation (3) in established range of variables M is built according to the following parameterization condition:

$$\sum_{i=1}^n \frac{\partial F}{\partial x_i} \frac{dx_i}{d\varphi} = 0 \quad (3)$$

This problem has a solution set, at that functions f_i in all cases depend on partial derivatives $\frac{dF}{dx_i}$. For analytical algorithm simplification it is concerned that functions f_i are

linear functions of mentioned above partial derivatives. This method of differential analyzers synthesis has an essential advantage: the argument φ , which is concerned to be a system parameter, can be any analytical function, what specifically lets realize the argument control, which is necessary for differential analyzer structure simplification.

The building of multi-coordinate control systems based on differential analyzers gives such advantages as:

- Simplification of control algorithm and automatic control system structure;
- Possibility to control the speed of affix movement without considerable complication of structure of automatic control system;

- Possibility of change-over of control system parameters for reproduction of affix movement on different topological manifold without considerable complication of structure of automatic control system;
- Possibility of optimal curves programming, i.e. such control design that provides maximum performance of manufacturing equipment while surface treatment;
- Possibility of universal software development for machines control for surface treatment.

Therefore, the motion program building level is built on the basis of differential analyzers, the block diagram of worked out control system and several examples of generated trajectories are presented on fig. 2.

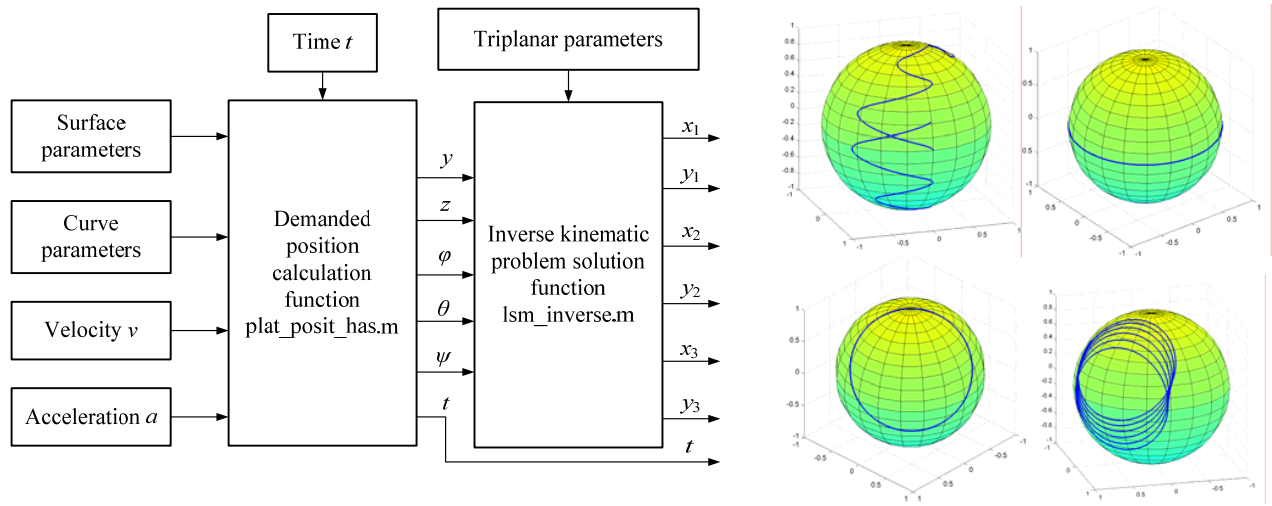


Fig. 2 Motion Program Building Block Diagram and Simulation Results

As it is depicted on fig. 2, the motion program building procedure generates trajectories on quadric surfaces with predefined velocity profile [4].

INVERSE KINEMATIC CALCULATION ALGORITHM

The inverse kinematic problem is based on geometrical Triplanar model presented on fig. 3. The appropriate secant planes CDR_1 , AER_2 and BFR_3 determine the variety of linear stepper motors positions R_1, R_2, R_3 on the stator.

Therefore, the following equations are built for the purposes of inverse kinematic problem solution:

$$A_1x + B_1y + C_1z + D_1 = 0 \quad (4)$$

where $A_1 = x_B - x_A$; $B_1 = y_B - y_A$; $C_1 = z_B - z_A$; $D_1 = -A_1x_D - B_1y_D - C_1z_D$.

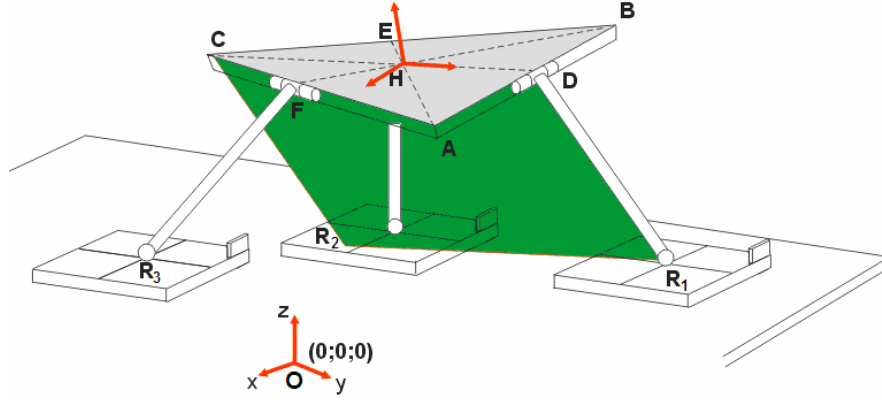


Fig. 3 Geometrical Triplanar Model

Taking into account z-coordinate of LSM, $z=0$ it is possible to build a system of equation which gives the following equations the solution of which is inverse kinematic problem solution:

$$\begin{cases} l = \sqrt{(x_D - x_{R1})^2 + (y_D - y_{R1})^2 + (z_D - z_{R1})^2}, \\ A_1 \cdot x_{R1} + B_1 \cdot y_{R1} + D_1 = 0. \end{cases} \quad (5)$$

$$\begin{cases} l = \sqrt{(x_E - x_{R2})^2 + (y_E - y_{R2})^2 + (z_E - z_{R2})^2}, \\ A_2 \cdot x_{R2} + B_2 \cdot y_{R2} + D_2 = 0. \end{cases} \quad (6)$$

$$\begin{cases} l = \sqrt{(x_F - x_{R3})^2 + (y_F - y_{R3})^2 + (z_F - z_{R3})^2}, \\ A_3 \cdot x_{R3} + B_3 \cdot y_{R3} + D_3 = 0. \end{cases} \quad (7)$$

The worked out inverse kinematic problem solution algorithm enables to implement real-time calculation structure which is based on analytical solution of equations (5...7).

LSM MODEL DESIGN AND VERIFICATION

For the purposes of closed loop control system implementation, the mathematical, computer models of linear stepper motors (LSM) LSM PF-211.HS was worked out and verified. The mathematical model of LSM was constructed of three basic sub models including electrical, electromagnetic and mechanical parts. Every sub model describes the appropriate energy conversion with non-linear transformation laws.

The model is based on description of electromagnetic module of LSM, the cross-section

of which is presented on fig. 4.

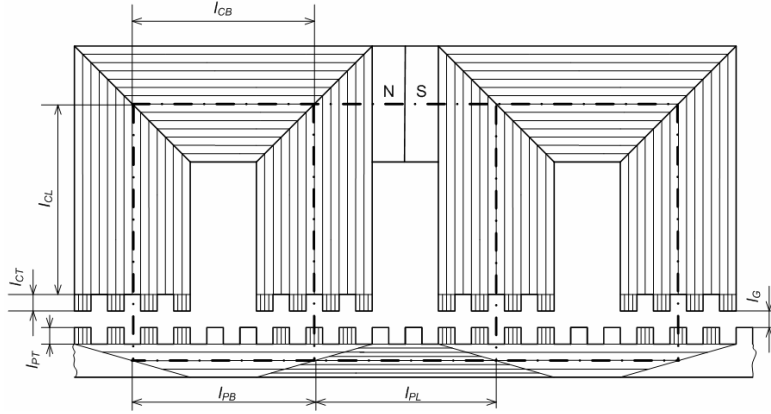


Fig. 4 The Electromagnetic Module Cross-Section

Based on physical electromagnetic module description, the following equation was found for the purposes of LSM PF-211.HS force description:

$$F = R_{G0} \frac{4\pi k_G}{p} \left(\Phi_{23} \Phi_{pm.A} \cos \frac{2\pi x}{\tau} - \Phi_{67} \Phi_{pm.B} \sin \frac{2\pi x}{\tau} \right) \quad (8)$$

The state space mathematical model was build on the basis of the following equations:

$$\begin{aligned} \dot{\Phi}_{23} &= f_1(\Phi_{23}, R_i(x, \Phi_i(i_A(\Phi_{23}, R_j(...)), R_k(...))), i_A, t) = \tilde{f}_1(\Phi_{23}, x, i_A, t) \\ \dot{\Phi}_{67} &= f_1(\Phi_{67}, R_i(x, \Phi_i(i_A(\Phi_{67}, R_j(...)), R_k(...))), i_B, t) = \tilde{f}_1(\Phi_{67}, x, i_B, t) \\ \dot{v} &= f_3(F(\Phi_{23}, \Phi_{67}, \Phi_{pm.A}(\Phi_i(i_A(\Phi_{23}, R_j(x, \Phi_j(...))), R_k(...))), \\ &\quad \Phi_{pm.B}(\Phi_i(i_B(\Phi_{67}, R_j(x, \Phi_j(...))), R_k(...))), F_d(v), t) = \tilde{f}_3(\Phi_{23}, \Phi_{67}, x, t) \\ \dot{x} &= v = \tilde{f}_4(v, t) \end{aligned} \quad (9)$$

Basing on these equations, one can mention that variables Φ_{23} , Φ_{67} , x and v are state space variables of direct drive. While the number of states are unique for each system, it should be emphasized that the choice of variables that are declared as state variables is rather a matter of convenience [1]. Using these equations, it is possible carry out computer simulation of direct drive. The inputs of the system are power amplifier currents i_A and i_B . The outputs which are to be monitored depends entirely on the application. In case presented x , v and F are output variables.

To verify worked out model, Identification Toolbox of MATLAB was used. This tool helps verify mathematical model with high accuracy. During experiments, the model of motor LSM-211PF.HS was verified. Identification Toolbox needs some input and output data which represent control signals and system response. Basing on these data, the transfer

function of the system is built, and, using one of identification techniques, the model transfer function is constructed. For the case of LSM-PF.211.HS motor verification a hall-effect sensor was used, as this is a standard option of this class of drives.

For the purposes of experimental data acquisition, a test bench was implemented, and direct drive transient process signals were measured and processed. The signals were measured and processed with different acceleration, velocity and travel tasks, to provide as much as possible information for analysis. The measurements were carried out using specified equipment on Ruchservomotor enterprise. Basing on experimental data and data acquired during computer simulation, transfer functions of direct drive were built. The analysis of model adequacy was carried out using ARX and PEM methods [6]. Transient responses of model worked out and real direct drive were acquired and compared. As the result, the built mathematical model is adequate up to 91%.

CONCLUSION

The hierarchical control system of Triplanar is described in the paper. It includes motion program building level based on holonomic automatic systems, inverse kinematic problem algorithm built on the basis of analytical geometry approaches used for procedure simplification, and LSM control system design and verification with the help of MATLAB software set.

References:

- [1] Homepage Mechatronik Laboratorium Paderborn, Universität Paderborn
- [2] Karpovich S., Rusetsky A., Liashuk Y., Matiushkov V. The Optimal Designing of Precision Coordinate Systems and Mechanisms of Electronic Technology Production Equipment.: Minsk, "Integral", 1999 (in Russian)
- [3] Karpovich S., Mezinsky Y. Design Aspects of Flexible Manufacturing Systems with Linear Stepping Motors // Proceedings of 41th Internationales wissenschaftliches Kolloquium. Ilmenau, Germany, 1996. - P. 166-170.
- [4] Zimmermann K., Ahranovich A., Karpovich S. Analysis and Synthesis of Differential Analyzers for Holonomic Automatic Systems // Scientific Proceedings. - Vol.1. - Aachen: Shaker Verlag, 2004. - p.246-251
- [5] Ahranovich A., Zimmermann K., Karpovich S. Investigating the Ability of Holonomic Automatic Systems` Dynamics Control // Proceedings of 50th International Scientific Colloquium, Ilmenau (Germany), September 19-23, 2005. - TU-Ilmenau, 2005. - p.127-128
- [6] Ljung L. System Identification: Theory for the User. Prentice-Hall, Englewood Cliffs, NJ, 1998. 150P

Authors:

Dipl.-Ing., Post graduate student Aliaksandr Ahranovich
Prof., Dr.-Eng. Habil Svyatoslav Karpovich
Belarusian State University of Informatics and Radioelectronics, P.Brovki Str. 6,
220027 Minsk Belarus
Phone: +375 (17) 293-88-30
E-mail: mmts@bsuir.unibel.by

Uni. prof. Dr.-ing. habil. Klaus Zimmermann
Technical University Ilmenau
D-98684 Ilmenau
E-mail: klaus.zimmermann@tu-ilmenau.de